Vol. LI *October, 1926* *No. 4*

BIOLOGICAL BULLETIN

GENETIC STUDIES IN POULTRY.[1]

I. The Sex Ratio in the Domestic Fowl.

W. V. LAMBERT and C. W. KNOX.

Introduction.

In comparison with mammals the sex ratio in birds has been studied by relatively few investigators. The first report on the sex ratio in birds appears to have been made by Darwin in 1871. He noted that the per cent. of males to females in 1,001 chickens raised by Stretch was 48.65. Field (1901) in 2,105 chickens reported a sex ratio of 44.63, Thomsen (1911) in 805 observations a sex ratio of 47.82, Pearl (1917) in 22,791 cases a percentage of 48.57 males, Crew and Huxley (1923) a sex ratio of 49.26 in a total of 753 chicks and embryos examined, Jull (1924) a sex ratio of 48.88 on 2,396 individuals sexed, and Musschl (1924) a percentage of 52.24 males from a total of 1,514 chicks upon which observations were made. In pigeons Cole and Kirkpatrick (1915) found that the per cent. of males to females was 51.06 on a total of 1,800 squabs and embryos examined.

The above data represent the total ratios observed by the various investigators on living chicks and dead embryos. With respect to the prenatal sex ratio, however, the data are less extensive, although the sex of the chicken may be quite readily told macroscopically by the ninth day of incubation. Of those reporting on the prenatal sex ratio, Pearl (1917) has the most extensive data, and he gives a sex ratio of 48.3 from a total of 1,921 embryos dying between the tenth day of incubation and

[1] Paper No. 12 from the Department of Genetics coöperating with Poultry Husbandry, Iowa State College, Ames, Iowa. The writers are indebted to Professor H. A. Bittenbender for permission to use the material for this study and to Doctor E. W. Lindstrom for valuable suggestions.

hatching. Jull (1924) found a sex ratio of 47.18 in embryos dying after the eleventh day of incubation taken as an average of the results of continuous hatches throughout a three-year period. Thomsen (1911) in a total of 805 embryos examined before hatching found a ratio of 47.82, while Crew and Huxley (1923) observed a prenatal sex ratio of 45.24 out of a total of 420 embryos examined. In the latter case, some of the parents of the embryos were subjected to treatment with a thyroid extract.

Material and Methods.

The material for the present study was obtained primarily from the F_1 and F_2 generations and backcross chicks of crosses made between the Rhode Island Red and White Leghorn breeds, and also of F_1 data from crosses made reciprocally between the Black Langshan and White Plymouth Rock, the Black Langshan and Buff Orpington, and the White Plymouth Rock and Buff Orpington. In addition a number of observations were made on data from the White Leghorn breed.

All eggs were candled on the sixth, twelfth, and eighteenth days of incubation, and embryos found dead on these respective days were classified as D_1, D_2 and D_3. All embryos found dead between the eighteenth day of incubation and the day of hatching were listed as dead in the shell (*DS*). All chicks of the D_3 and *DS* classes, and chicks dying before it was possible to determine their sex from the external appearance, were dissected and the sex determined in that manner. The sex ratio on all living chicks was determined as soon as that was possible from their external appearance.

In 1925 the total sex ratio from 121 hens between the hatching dates of March 4 and May 6 was obtained with the exception of losses due to straying, loss of bands, predatory enemies, and losses due to fire which destroyed a portion of the hatch of one week. Data are given showing the number of individuals upon which the sex was not determined, but there is no reason to believe that the sex ratio of these chicks would have deviated greatly from the ratios observed.

In addition to the above, observations were made upon the live chicks and dead embryos of a number of hens during the years

1924 and 1925. These data are not continuous throughout the hatching season but represent only data secured at various intervals during the hatching season. The record on any one hen, however, is complete for the period in which the observations were made.

The sex ratio as used herein expresses the percentage of males to females in the population.

Results.

During the two years a grand total of 2,910 embryos and living chickens was examined. Of these 1,488 were males and 1,422 females or a sex ratio of 51.13. The results of the two years records are shown in Table I.

Table I.

The Total Number of Males and Females Observed and the Sex Ratio Found in the Chicks Hatching and in the Dead Embryos.

Year.	D_3.			*DS*.			Chicks Hatching.			Totals.		
	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂
1924......	13	8	61.90	26	34	43.33	68	81	45.64	107	123	46.52
1925......	126	102	55.26	374	365	50.61	881	832	51.43	1,381	1,299	51.53
Totals....	139	110	55.82	400	399	50.06	949	913	50.97	1,488	1,422	51.13

It will be noted here that the sex ratio in each class, namely D_3, *DS* and living chicks, is over fifty, it being 55.82 in the D_3, 50.06 in the *DS* and 50.97 in the living chicks. The results in each of the two years are not in very close agreement although the same general trend exists in each case.

From the 2,910 individuals shown in Table I. a complete sex ratio was secured on 2,266 chicks and embryos developing from the eggs produced by 121 hens during the season of 1925. Of all eggs used from this group of 121 hens and that developed beyond the twelfth day of incubation, barring those chicks lost due to the causes previously mentioned, a complete sex ratio was obtained between the hatching dates of March 4 and May 6. These data are shown in Table II.

Table II.

The Complete Sex Ratio for Dead Embryos and Chicks Hatching During Successive Two-week Intervals for 121 Hens During the Normal Hatching Season of 1925.

Hatching Dates.	*D*₃.			*DS*.			Chicks Hatching.			Totals.		
	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂
March 4 and 11	11	6	64.70	71	51	58.20	134	155	46.37	216	212	50.47
March 18 and 25	28	25	52.83	66	78	44.44	113	123	47.88	207	226	47.81
April 1 and 8	45	36	55.55	86	58	59.72	243	207	54.00	374	301	55.41
April 15 and 22	15	9	62.50	29	32	47.54	176	174	50.28	220	215	50.57
April 29 and May 6	3	6	33.33	12	18	40.00	138	118	53.91	153	142	51.86
Totals	102	82	55.43	264	237	52.69	804	777	50.85	1,170	1,096	51.63
Per cents	4.50	3.62		11.65	10.46		35.48	34.29		51.63	48.37	

Of the 2,266 individuals shown in the above table 8.12 per cent. were embryos dead between the twelfth and eighteenth days of incubation, 22.11 per cent. between the eighteenth and twenty-first days, and 69.77 per cent. were chicks sexed after hatching. It is interesting to note in this connection that the most critical period of development is apparently between the eighteenth and twenty-first days of incubation. Of all eggs set and dying in the embryonic stage, 361 or 34.5 per cent. died before the twelfth day of incubation, 184 or 17.6 per cent. between the twelfth and eighteenth days, and 501 or 47.9 per cent. during the last three days of incubation.

The sex ratio is listed each week for the three classes D_3, DS and chicks hatched respectively, together with the totals for each week and the total ratio of each class for the entire period with the corresponding ratio of males. These data in Table II. represent a total of 79.20 per cent. of all fertile eggs set during this time. Of the remaining 20.8 per cent. upon which the sex was not determined 12.62 per cent. or 361 died before the twelfth day of incubation and 8.18 per cent. or 234 were lost due to the causes listed.

In the D_3 class with the exception of the last two weeks interval the sex ratio is comparatively high, ranging from 52.83 to 64.70. However, no general trend is apparent during the consecutive intervals as the highest sex ratio appears in the interval from March 4 to 11 and the next highest in the period of April 15 to 22.

Of those embryos dying between the eighteenth and twenty-first days of incubation no general trend of the sex ratio is likewise apparent. In general, however, the sex ratio is lower than among the D_3 class.

Of the chicks sexed after hatching no particular trend is noted in the sex ratio from the beginning to the end of the hatching season. The per cent. of males of the chicks hatching varies from 46.37 to 54.00 with an average of 50.85. From the total of 2,266 chicks and embryos examined 1,170 or 51.63 per cent. are males and 1,096 or 48.37 per cent. females.

Some of the data included in Table I. were not complete for the whole season. These were obtained in both 1924 and 1925 and were tabulated without regard to the week in which they were obtained. On a few of the hens only data from the dead embryos were included, whereas, in others both data from dead embryos and chicks were included. In all cases, however, where the sex ratio of chicks was determined it represented a total hatch of those particular hens for that period. In other words it represents the complete record of the hens for any one interval. These unclassified data appear in Table III.

TABLE III.

THE OBSERVED SEX RATIO IN SOME UNCLASSIFIED DATA OBTAINED DURING THE NORMAL HATCHING SEASONS OF 1924 AND 1925.

Year.	D_3.			DS.			Chicks Hatching.			Total.		
	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂	♂♂	♀♀	R♂♂
1924........	24	20	54.55	110	128	46.22	77	55	58.23	211	203	50.97
1925........	13	8	61.90	26	34	43.33	68	81	45.64	107	123	46.52
Totals......	37	28	56.92	136	162	45.64	145	136	51.60	318	326	49.38

The large number of chicks dead between the eighteenth and twenty-first days of incubation appearing in the 1924 data is due to the fact, as mentioned before, that in some cases only the dead embryos of certain hens were sexed.

In this as in the preceding tables no very definite trend to the sex ratio is apparent. While there seems to be an excess of males in the D_3 column and an excess of females in the DS column the numbers are probably not large enough to indicate a selective mortality at the different stages of incubation. This would appear especially true since no similar condition appears for the more extensive data shown in Table II. In the chicks hatching listed in Table III. a high sex ratio occurred in 1924 and a low sex ratio in 1925. Hence it would appear that the variations noted in this table are probably due to the small numbers.

From the methodological standpoint Pearl (1917) has indicated the advantage of basing the sex ratio on families of ten or more individuals. He has compared the mean sex ratio of families of various sizes and finds the following ratios in each:

	R♂♂
Families of 10 and over	48.57 ± 0.28
Families of 4–9 inclusive	49.39 ± 0.84
Families of 1–3 inclusive	55.07 ± 2.11
Families of 4 and over	48.80 ± 0.33
Families all sizes	49.45

It becomes apparent from these figures that the smaller families are more likely to show extreme values of the sex ratio. In fact, according to Pearl, ratios above 80 and under 20 occur very rarely in families of ten or more.

The ratio of males for different colonies in the present experiment together with the number of hens in each colony is shown in Table IV.

TABLE IV.

THE SEX RATIO FOR THE DATA SHOWN IN TABLE II. LISTED ACCORDING TO BREEDING AND COLONIES.

Breeding.	No. of Birds in Colony.	*D*3.		*DS*.		Chicks Hatching.		Total.		R♂♂
		♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	
F_2 (White Leghorn by Rhode Island Red)	17	11	9	44	56	188	202	243	269	47.46
F_1 (Black Langshan ♂, Buff Orpington ♀♀, White Plymouth Rock ♀♀)	10	9	7	26	24	41	42	77	73	51.33
White Leghorn	13	14	11	19	21	73	52	106	84	55.79
F_1 (Buff Orpington ♂, White Plymouth Rock ♀♀, Black Langshan ♀♀)	9	13	3	8	8	62	69	85	82	50.90
F_1 (White Plymouth Rock ♂, Buff Orpington ♀♀, Black Langshan ♀♀)	7	2	4	17	9	30	26	49	39	55.68
F_1 ♀♀ (White Leghorn ♂)	12	8	10	31	21	83	74	122	106	53.51
F_1 ♀♀ (Rhode Island Red ♂)	11	16	11	17	24	79	76	112	111	50.22
F_1 ♂ (Rhode Island Red ♀♀)	11	8	6	24	20	54	51	86	78	52.44
F_1 ♂ (White Leghorn ♀♀)	11	19	12	12	14	43	49	74	76	49.33
White Leghorn	5	0	1	4	6	33	36	38	43	46.91
White Leghorn	15	2	8	62	34	114	91	178	135	56.87

The range in the data is from 46.91 in the smallest colony with a total of five birds to 56.87 per cent. males in a colony with fifteen birds. The average sex ratio for all colonies is 51.63.

Both the high and low sex ratios appear in colonies of White Leghorns. The individual range in the colony showing the lowest per cent. of males was from 33.3 to 66.7 per cent. In the colony showing the highest sex ratio the range was from 44.4 to 85.7 per cent. In tabulating this range only birds producing ten or more chicks and embryos that were sexed were included. This included all individuals in the small colony and fourteen out of the fifteen in the large colony. The average sex ratio in the last case when determined for the fourteen birds having 10 or more sexed offspring was 59.2. It was thought necessary in determining the range to include only birds having ten or more sexed offspring as any smaller number than that would hardly give a representative sample.

From the total of eleven colonies only three show sex ratios of less than 50. No relationship appears to exist between breeds and the sex ratio for the hybrids show about the same variation as do the pure breeds.

The Influence of Egg Weight and Production upon the Sex Ratio.

Jull (1924) found no relationship between average weight of eggs and the sex ratio, and Jull and Quinn (1925) found no correlation between the weights of individual eggs and the chicks hatching from them.

Since the average egg weights for all F_1 hens used in this experiment were available as well as the sex ratio for these hens, a correlation between these two variables has been calculated. In this study only those hens that have a total of ten or more chicks or embryos upon which the sex had been determined were included, the total number being thirty-nine. The correlation coefficient for egg weight and percentage of males was -0.060 ± 0.108. This correlation being smaller than its probable error certainly indicates that no direct relationship exists between these variables.

On this same group of F_1 birds the rate of production preceding the hatching season has not influenced the sex ratio. In this calculation the percentage rate of production was used. This rate of production was used because the birds began laying at

TABLE V.

THE CORRELATION BETWEEN THE AVERAGE INDIVIDUAL EGG WEIGHTS, THE ACTUAL EGG PRODUCTION DURING THE HATCHING SEASON, AND THE RATE OF ANTECEDENT PRODUCTION RESPECTIVELY, WITH THE SEX RATIO AS THE DEPENDENT VARIABLE.

Variables.	Range.	Mean.	Coefficient of Variability.	Standard Deviation.	Correlation Coefficient.
A. Average individual egg weights (grams)	46.9–60.3	53.07 ± 0.32	7.51 ± 0.57	2.93 ± 0.22	*A–D* −0.060 ± 0.108
B. Actual egg production during hatching season	22–47	36.50 ± 0.65	15.51 ± 1.20	6.05 ± 0.46	*B–D* −0.009 ± 0.108
C. Antecedent egg production (per cent.)	11.1–57.9	43.00 ± 1.16	28.35 ± 2.22	10.49 ± 0.82	*C–D* −0.048 ± 0.111
D. Sex ratio (per cent.)	37.0–81.8	51.26 ± 1.06	25.03 ± 1.91	9.76 ± 0.75	

different dates and the rate was determined by dividing the total number of eggs laid by the number of days between the date of first egg and the beginning of the hatching season. The correlation cœfficient in this case was -0.048 ± 0.111. This correlation likewise is not significant and indicates, in this particular group of birds, that preceding production has not influenced the sex ratio.

In a study of the sex ratio based on hatches throughout the entire year Jull (1924) found a correlation of -0.704 ± 0.031 between the sex ratio and antecedent egg production. As the season advances the ratio of males decreases, and Jull concludes that the cause for this decrease is directly related to the antecedent egg production.

The rate of egg production during the hatching season, likewise, was found not to have influenced the sex ratio in this group of birds. The correlation cœfficient between total production during the hatching season and the sex ratio was -0.009 ± 0.108. This correlation, like the two preceding, is not significant being much smaller than its probable error.

Since the correlation cœfficients in all three cases were negative and smaller than their respective probable errors the conclusion is justified that neither mean egg weight, as measured for each bird nor the rate of production both preceding and during the hatching season has influenced the sex ratio. In other words there is no tendency for those birds laying the fastest or laying the heaviest eggs to produce more or less males than the birds producing the fewest or the lightest eggs.

The correlations between these three variables together with their respective ranges, means, cœfficients of variability, and standard deviations are shown in Table V.

Discussion.

The data presented herein for the most part show a higher sex ratio than has been reported by other investigators. Musehl (1924) reporting a sex ratio of 52.24 per cent. is the only one reporting a higher percentage of males. Cole and Kirkpatrick (1915) report approximately the same sex ratio in pigeons as is reported by the present writers, namely 51.06 per cent. All other studies have indicated a ratio of less than fifty per cent. males, both for living chicks and dead embryos. No reason for this higher sex ratio is apparent. It is true that a number of the birds were lost due to various causes but the writers have no reason to believe that there was a selective mortality of the chicks that were lost.

The proportion of males among the embryos dying between the twelfth day and eighteenth day of incubation is rather high, being 55.82. However, if reference is made to Table IV. it may be seen that it does not hold consistently true that the males exceed the females in the D_3 class. In the *DS* class there is practically an equality of males and females, the ratio of males being 50.06. All previous investigators reporting on the prenatal sex ratio alone in birds have reported a sex ratio less than fifty per cent. They likewise have seemed agreed that a selective mortality of one sex or the other previous to hatching does not occur.

The number of birds upon which the correlations have been calculated is small but the results found here are in general agreement with those of other investigators. More of the birds were not included in these studies because the mean egg weight varies for different breeds and in most cases the antecedent egg product on on the birds used in the various crosses was not known.

Summary.

1. The sex ratio for 2,910 chicks and embryos examined was 51.13.

2. The sex ratio for total living chicks was 50.97, for embryos dying between the eighteenth and twenty-first days of incubation 50.06, and for embryos dying between the twelfth and eighteenth days 55.82 per cent.

3. No tendency for an increase or a decrease in the sex ratio as the hatching season progressed was noted.

4. The sex ratio of hybrid birds is approximately the same as for that of the pure breeds observed.

5. No relationship between the sex ratio and the factors of mean individual egg weight, antecedent egg production, and actual egg production during the hatching season is apparent.

The respective correlations found between these variables were -0.060 ± 0.108; -0.009 ± 0.108; and -0.048 ± 0.111.

LITERATURE CITED.

Crew, F. A. E., and Huxley, J. S.

'23 The Relation of Internal Secretion to Reproduction and Growth in the Domestic Fowl. I. Effect of Thyroid Feeding on Growth Rate, Feathering, and Egg Production. Vet. Jour., 79: 343–348.

Cole, L. J., and Kirkpatrick, W. F.

'15 Sex Ratios in Pigeons together with Observations on the Laying, Incubation and Hatching of the Eggs. Rhode Island Agric. Exp. Sta. Bull., 162: 463–512.

Darwin, Charles.

'71 The Descent of Man. Vol. 1, p. 296. D. Appleton and Co., New York.

Field, G. W.

'01 Experiments on Modifying the Normal Proportion of the Sexes in the Domestic Fowl. BIOL. BULL., 2: 360–361.

Jull, M. A.

'24 The Relation of Antecedent Egg Production to the Sex Ratio of the Domestic Fowl. Jour. Agr. Res., 28: 199–224.

Jull, M. A., and Quinn, J. P.

'25 The Shape and Weight of Eggs in Relation to the Sex of Chicks in the Domestic Fowl. Jour. Agr. Res., 29: 195–201.

Mussehl, F. E.

'24 Sex Ratios in Poultry. Poult. Sci., 3: 72–73.

Pearl, R.

'17 The Sex Ratio in the Domestic Fowl. Proc. Amer. Phil. Soc., 56: 416–436

Thomsen, E.

'11 Die Differenzierung des Geschlechts und das Verhältnis der Geschlechter beim Hünchen. Arch. Entwick. Organismen 31: 512–530.